Army Research Laboratory

Comparison of Army Hand and Arm Signals to a Covert Tactile Communication System in a Dynamic Environment

by Rodger A. Pettitt, Elizabeth S. Redden, and Christian B. Carstens

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14. ABSTRACT
This study was conducted jointly by the U.S. Army Research Laboratory and the University of Central Florida. The purpose of this experiment was to evaluate Soldiers' abilities to interpret and respond to tactile commands compared to their abilities to interpret and respond to standard visual hand and arm signals given from leaders in front of and behind them during movement. The tactile belt, developed by UCF, consists of eight tactors (tactile drivers) arranged equidistant around the Soldier's waist. Individual or multiple tactors can be activated by an operator using a remote wireless control system. Infantry Soldiers, wearing their standard uniforms and body armor, negotiated a woodland individual movement technique (IMT) obstacle course while simulating a combat patrol. Tactile and visual hand and arm signals were sent to the Soldiers as they negotiated the course. The accuracy of signal interpretation and response times was recorded. The tactile signal patterns were intuitive and easy for the Soldiers to understand; less than 10 minutes' training was required for the Soldiers to become accurate in interpreting the four tactile signals used during the experiment. Results demonstrated that Soldiers performing IMT were able to receive, interpret, and accurately respond to the tactile commands faster than when the information was passed by leaders in the front of a wedge formation and leaders in the back of a wedge formation using conventional hand and arm signals. Soldiers also commented that they were better able to focus more attention on negotiating obstacles and on area situational awareness when receiving tactile signals than when maintaining visual contact with their leaders in order to receive standard hand and arm signals.

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Executive Summary

This study was conducted by the U.S. Army Research Laboratory's Human Research and Engineering Directorate with a state-of-the-art tactile prototype display developed by the University of Central Florida. The purpose of this experiment was to evaluate Soldiers' abilities to interpret and respond to tactile commands compared to their abilities to interpret and respond to standard visual hand and arm signals given from leaders in front of and behind the Soldiers during movement. The evaluation was conducted with infantry Soldiers who negotiated a woodland individual movement technique (IMT) obstacle course while simulating a combat patrol. Tactile and visual hand and arm signals were sent to the Soldiers as they negotiated the course while wearing their standard uniforms and body armor. Accuracy of signal interpretation and response times were documented.

The tactile signal patterns were found to be intuitive and easy for the Soldiers to understand. Very little training time (less than 10 minutes) was required for Soldiers to become accurate in interpreting the four tactile signals used during the experiment. Results demonstrated that Soldiers performing IMT were able to receive, interpret, and accurately respond to the tactile commands faster than when the information was passed by leaders in the front of a wedge formation and leaders in the back of a wedge formation using conventional hand and arm signals. Soldiers also commented they were better able to focus more attention on negotiating obstacles and on area situational awareness when receiving tactile signals than when maintaining visual contact with their leaders in order to receive standard hand and arm signals.

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1. Introduction

1.1 Statement of the Problem

The potential for information overload in dismounted Soldier organizations becomes greater as Army systems increase in complexity. The challenge for the dismounted infantryman is to monitor visual and auditory communication networks while maintaining situational awareness (SA) of his local environment. Concurrent performance of scanning and communication tasks has been shown to produce very high workload (Mitchell, Samms, Glumm, Krausman, Brelsford, & Garrett, 2004). One of the reasons why the Situational Understanding as an Enabler for the Unit of Action Maneuver Teams (SU) Army Technology Objective (ATO) was developed was to address the issues associated with information display for the dismounted Soldier. The ATO supports research focused on reducing the potential mental workload of Soldiers who often perform multiple tasks simultaneously. A primary theoretical basis for the ATO is Multiple Resource Theory (MRT) which appears to be a useful basis for designing interfaces for applications in which individuals perform several tasks at the same time (Wickens, 1991).

Display interventions have been particularly effective in situations when individuals have multiple demands for attention. MRT suggests that distributing tasks and information across various sensory modalities might be an effective display intervention. MRT proposes that humans have a finite capacity for processing information (Wickens, 1991). Off loading some of the information to other modalities can reduce dual task interference, which should lead to more efficient processing and improve task-sharing performance (Sklar & Sarter, 1999). In situations when demands on audition and vision are high[1], it may be beneficial to include the tactile communication modality for intra-squad communication. Recently, tactile displays have shown promise when used as communication systems for pilots and astronauts to aid in spatial orientation by providing directional cues (Gilliland & Schlegel, 1994; Jones & Nakamura, 2003), as navigational aids (van Erp, 2005; Elliott, Redden, Krausman, Carstens, & Pettitt, 2005), as target cues (Glumm, Kehring, & White, in process), and as alerts for display operators (Krausman, Elliott, Redden, & Petrov, 2005). Tactile displays may have the capacity to communicate even more complex messages.

Challenges are involved in conveying battlefield information to the dismounted Soldier in a manner that enhances his ability to manage the information and thus increase his or her SA. The research cited suggests that allocating information and tasks among different senses may lessen channel bottlenecks and processing limitations, thus enhancing the information management and situational understanding of Soldiers. With proper implementation, the use of tactile displays for the Soldier could reduce demands on and interference with the Soldiers' visual and auditory

[1]Such as a dismounted Soldier listening to sounds announcing the enemy's approach while looking for signs of enemy ambush.

channels, thereby improving overall performance. The present study is an investigation of the efficacy of translating infantry hand and arm signals into a vocabulary of tactile commands. The following issues were addressed: Can Soldiers easily distinguish one tactile command from another? Can they quickly learn a limited vocabulary of tactile signals? How well and how quickly can they understand and respond to tactile commands while performing individual movement techniques (IMT) in a dynamic environment?

1.2 Objectives

- Are the Soldiers able to interpret and respond to tactile commands as efficiently as they can interpret and respond to hand signal commands in a dynamic environment?
- Does the use of the tactile system impair the ability of the Soldiers to complete the obstacles on the woodland IMT course?

2. Method

2.1 Overview

The purpose of this experiment was to provide an evaluation of a covert tactile communication system. The system used in this experiment was designed by researchers at the University of Central Florida (UCF) to communicate a variety of commands corresponding to standard Army hand signals. Soldiers were given commands by hand and arm signals or by covert tactile signals while they moved through a woodland IMT course. Soldiers wore their fighting loads, including interceptor body armor (IBA) without ceramic insert plates, and carried simulated personal weapons (M4 carbines). After being trained to use the system, each Soldier completed the IMT course three times while receiving tactile signals, hand and arm signals from a leader in front of the Soldier, and hand and arm signals from a leader behind the Soldier. The systems were compared for objective performance data, data collector observations, and answers to Soldier questionnaires.

2.2 Participants

Thirty Soldiers from the Infantry Training Brigade (ITB), Fort Benning, Georgia, participated in the assessment. The assessment was conducted over a 3-day period. It was made clear that Soldier participation in the study was voluntary. To ensure the voluntary nature of participation, copies of the consent form were provided to all participating subjects who were then given an opportunity to review the assessment objectives. Their questions were answered by the investigators, and they were asked to sign consent forms indicating their informed voluntary consent to participate. The Soldiers were informed that if they chose not to participate, they

could convey that choice privately to the assessment manager who would have informed that Soldier's unit supervisor, without elaboration, that the Soldier did not meet study criteria. Had any designated subject chosen not to participate in any of the exercises, the unit would have been asked to recruit another volunteer. All tasks used for this study were a normal part of the Soldier's job. The Soldiers completed this assessment using the tactile system while wearing their Army combat uniform (ACU) and standard fighting load. They carried a training device simulating the M4 during the IMT course.

2.2.1 Pre-test Orientation and Volunteer Agreement

The Soldiers were given an orientation about the purpose of the study and their participation. They were briefed about the objectives and procedures for each exercise, as well as the equipment they were required to use throughout the investigation. They were also told how the results would be used and the benefits the military could expect from this investigation. Any questions the subjects had regarding the study were answered. In addition, a volunteer agreement affidavit was explained and its contents were verbally presented. The Soldiers were then given the volunteer agreement affidavit to read and sign, and they all signed.

2.2.2 Medical Review and Screening

At the outset of the assessment, the investigators asked the Soldiers if any of them had a medical profile or history that would jeopardize them if they participated in the study. Soldiers were also asked to complete a medical status form.

2.2.3 Demographics

Demographic data were taken for each Soldier. Data concerning their physical characteristics, infantry experience, and training were included in the demographic data form.

2.3 Instruments and Apparatus

2.3.1 Tactile System

The tactile system used during this experiment was developed by the UCF under a Defense Advanced Research Projects Agency (DARPA) contract (number DAAE0703CL143). UCF assembled a team of scientists, product designers, builders, programmers, and Soldiers who employed their knowledge of human physiology and battlefield tactics to construct a tactile display system that is reliable and easy to use. This system is capable of remotely conveying covert signals, cues, and messages by touch. Each system consists of a tactile display worn around the waist with a receiver unit that was stowed in the cargo pockets of the Soldiers during negotiation of the obstacle course. The display itself consists of eight tactile drivers (tactors) that create a strong localized sensation on the body. The tactors can be activated individually, sequentially, or in groups to provide a specific sensation or to create unique patterns of vibration

analogous to standard Army hand signals that are used when Soldiers are in visual contact. The control unit receives wireless signals and converts them into recognizable patterns of vibration. A more detailed description of the tactile system is presented in the contractor's report in appendix A.

For this experiment, the system used a personal digital assistant (PDA) with programmed buttons to initiate transmission for four basic commands as tactile patterns designed to be analogous to standard Army hand signals. The four commands used in this experiment (attention, halt, move out, and rally) represent only a few of the many commands and types of information that can be conveyed by the system (see the contractor's report in appendix A for a detailed description of the tactile signals). The tactile representations of these signals were designed in a collaborative effort of scientists at UCF and a consultant group of subject matter experts (SMEs) consisting of former U.S. servicemen. These sequences were then slightly modified in laboratory testing at UCF and developed for this field test.

2.3.2 IMT Course

The IMT course requires Soldiers to use most urban and non-urban tactical maneuvers and IMT. It requires Soldiers to execute a variety of individual movements and assume a variety of positions while maneuvering through, over, under, and around obstacles. The primary advantages of using this course rather than actual terrain are control, standardization, and repeatability. The obstacles were categorized according to the activity the Soldier was performing at the time he was given a command. The four obstacle types were patrolling, crawling, firing, and climbing. Soldiers initially walked through the course, and each obstacle and position was explained before the first record trial was run. In addition, all Soldiers completed one familiarization trial wearing their uniform, standard fighting load, and tactile belt and carrying their assigned weapon. Appendix B contains a sketch of the course. A description of each event and instructions for executing the event are provided next.

- Starting Point. (Patrolling) The starting point is clearly marked with a white line that spans the width of both lanes on the course. The course requires the Soldier to begin in the upright standing position with his weapon held at "port arms". On the command "go" from the data collector, the trial begins and the Soldier moves approximately 30 meters to obstacle A. Once the course is started, he follows his team leader at a distance of approximately 10 meters through the entire course, executing each obstacle along the way, until the end is reached.

- Obstacle A, Pipe Crawl. (Crawling) The pipe is 6 m long and 1 m in diameter and is made of corrugated steel. It has a ridged surface, and Soldiers wear elbow and knee pads to avoid injury. The Soldier moves as quickly as possible to complete the obstacle without causing injury to himself or damage to his equipment. Once through the pipe crawl, the Soldier moves to obstacle B.

- Obstacle B, Zigzag. (Patrolling) The zigzag is 1.6 m tall, 14 m in length, and approximately 1 m in width. It consists of three turns (approximately 90 degrees each) within the lane. The framework is constructed of wood with mesh wire installed between the two lanes and on the outside framework of each lane. The zigzag requires the Soldier to proceed through the obstacle as quickly as possible without causing any injury to himself or damage to his equipment. Once through the zigzag, the Soldier moves around the first bend to obstacle C.
- First Turn. (Patrolling) On the first turn, the Soldier follows a 180-degree bend in the course which ends at the 2-foot wall kneeling firing position.
- Obstacle C, 2-foot Wall Kneeling Firing Position. (Firing) Upon entering the station, the Soldier assumes a kneeling supported firing position. Once completed, the Soldier moves to obstacle D.
- Obstacle D, Mound. (Patrolling) The mound is approximately 10 m long, 2 m wide, and 3 m tall with a 30-degree sloped incline and decline along the route of movement. The Soldier ascends and descends the mound and then moves to obstacle E.
- Obstacle E, Prone Unsupported Firing Position Station. (Firing) The prone unsupported firing position station is 2 m long by 1 m wide. The Soldier enters the station and assumes a prone unsupported firing position. Once completed, the Soldier moves to obstacle F
- Obstacle F, Low Crawl. (Crawling) The low crawl is 13 m long and 3 m wide with an overhead cover of mesh wire approximately 0.6 m off the ground. The Soldier completes the obstacle as quickly as possible using correct low crawl techniques. After completing the low crawl, the Soldier proceeds around the second turn to obstacle F.
- Second Turn. (Patrolling) On the second turn, the Soldier follows a 180-degree bend in the course which ends at the combat roll.
- Obstacle F, Combat Roll. (Firing) Each lane of the combat roll station is about 6 m long and 1 m wide. The Soldier hastily assumes the prone position immediately after entering the station. He then executes a full combat roll to the left or right, pushes off the ground using the butt stock of the weapon, executes a 3- to 5-second rush, and returns to the prone. The Soldier then executes a full combat roll to the left or right, pushes off the ground using the butt stock of the weapon, and moves to obstacle G.
- Obstacle G, High Crawl. (Crawling) Each lane of the high crawl is 13 m long and 3 m wide with an overhead cover of mesh wire approximately 1 m off the ground. The Soldier moves as quickly as possible, using correct high crawl procedures, to negotiate the full length of the obstacle. Once through the high crawl, the Soldier moves to obstacle H.
- Obstacle H, Kneeling Firing Position Station. (Firing) The kneeling firing position station provides a wooden support 2 m wide, 1 m tall, and 13 cm deep for the Soldier to support

the weapon against during target acquisition and engagement. Upon entering the station, the Soldier assumes a kneeling supported firing position. Once completed, the Soldier moves to obstacle I.

- Obstacle I, High Wall. (Climbing) The high wall is made of wood, is 1.4 m tall, 1.8 m wide, and 13 cm deep. The Soldier climbs over the obstacle without causing any personal injury or damaging equipment while maintaining control of the weapon at all times. Once the high wall is cleared, the Soldier moves to obstacle J.

- Obstacle J, Prone Supported Firing Position Station. (Firing) The prone firing position station is 2 m long by 1 m wide with sandbags provided to support the weapon. The Soldier enters the station and assumes a prone supported firing position. Once completed, the Soldier moves to obstacle K.

- Obstacle K, Urban Wall Window Kneeling Firing Position. (Firing) The Urban wall replicates several urban obstacles. Upon reaching the wall, the Soldier assumes a kneeling firing position at the opening that represents a window. Once completed, the Soldier proceeds to obstacle L.

- Obstacle L, Urban Wall Ladder. (Climbing) At Obstacle L, the Soldier climbs a ladder over the top of the urban wall and climbs down the ladder on the opposite side of the wall and moves to obstacle M.

- Obstacle M, Stairs. (Climbing) The stairs are made of wood. Five steps lead up to a platform and five steps lead down. Once the stairs are completed, the Soldier moves to the end point.

- End Point. (Patrolling) The Soldier moves approximately 30 meters and completes the IMT course.

2.3.3 Questionnaires

Questionnaires were designed to elicit Soldiers' opinions about their performance and experiences for each iteration while they wear the tactile system. The questionnaires were designed to enable Soldiers to rate the ease of receiving and understanding visual and tactile communications while negotiating obstacles and their overall experience with the tactile system. Questionnaires were administered to each Soldier at the completion of each iteration.

2.4 Procedures

2.4.1 Training

Before beginning training, the Soldiers received a roster number, which was used to identify them throughout the assessment. A UCF representative presented a course on the use and fit of the

tactile system and the tactile signal interpretation. Approximately 7 to 10 minutes of familiarization with the tactile system were given to Soldiers before they completed the obstacle course. Familiarization for every Soldier consisted of approximately 17 repetitions of the four tactile signals: three repetitions without fighting loads, four times with fighting loads, and two times each with fighting loads in the kneeling, prone, combat roll, walk, and run positions/actions. Just before the Soldier started the obstacle course, a researcher presented and reviewed each tactile signal again to ensure that the Soldier understood the signals. A representative from the U.S. Army Research Laboratory's Human Research and Engineering Directorate also presented a refresher course on hand and arm signals. Soldiers were trained until they were 100% accurate on all signals. Each Soldier was retested on all the signals before each obstacle course iteration to ensure that learning decay had not taken place. Upon completion of the training, the Soldiers were given a questionnaire designed to assess their perception of the training adequacy.

The requested Soldiers were in a military occupational specialty (MOS) that requires performance of mobility and portability maneuvers (movement to contact and assault maneuvers), and movement as a dismounted element that is associated with their profession (Department of Army, 1999). No specialized experience was required. However, the Soldiers were shown how to negotiate the IMT course safely and were trained in specific procedures as required. Additionally, the Soldiers walked through the course at a slow speed to better familiarize them with the course, as well as reduce Soldier risk during actual course execution. Before the record trials were run, Soldiers participated in a practice trial on the obstacle course, during which, hand and arm signals and tactile signals were sent.

2.4.2 IMT Course Trials

Soldiers completed three iterations of the IMT course according to the matrix shown in table 1. During each iteration, Soldiers wore the tactile system and were led through the IMT course by a team leader and were followed by a squad leader. These positions are consistent with a Soldier acting as a member of a squad in a wedge formation. The team leader was designated to communicate visual hand and arm signals from the front and the squad leader from the rear. Tactile commands were communicated to the Soldier by a controller operating the control unit. The controller operating the control unit stayed within 10 to 15 meters of the Soldier as he moved through the course. A data collector recorded the time from the command's initiation until it was acknowledged by the Soldier and whether the correct response was given. Before negotiating the course, Soldiers were briefed that signals could be received at any point during the course from the team leader (front), squad leader (rear), or through the tactile belt. Soldiers were instructed to tell the data collector the meaning of the signal when a signal was received visually or tactilely. Soldiers were also instructed to maintain a 10- to 15-meter interval from the team leader while moving through the course. As a visual distraction task, Soldiers were told to look for Special Forces, Airborne, and Ranger tabs which were placed at various locations on the course and to scan the woods for targets. At the completion of each course trial, a subjective

questionnaire was administered. In addition, data collector observations were recorded for each trial.

When Soldiers were not running the IMT course, they were kept out of view of the course so that they did not learn the sequence and location of signals.

Table 1. Treatment assignments.

Obstacle	**Activity Type**	**Signal**	**Communication Condition**
Pipe Crawl	Crawl	HALT	Tactile
1st Turn	Patrol	ATTENTION	Rear H & A
Prone Unsupported	Fire	ATTENTION	Front H & A
2nd Turn	Patrol	MOVE OUT	Tactile
High Crawl	Crawl	RALLY	Rear H & A
High Wall	Climb	MOVE OUT	Tactile
Urban Window	Fire	HALT	Rear H & A
Stairs	Climb	RALLY	Front H & A
Iteration 2			
Obstacle	**Activity Type**	**Signal**	**Communication Condition**
Zigzag	Patrol	ATTENTION	Front H & A
2ft Wall Kneel	Fire	ATTENTION	Rear H & A
Low Crawl	Crawl	RALLY	Front H & A
Combat Roll	Fire	HALT	Tactile
High Crawl	Crawl	HALT	Rear H & A
High Wall	Climb	RALLY	Rear H & A
Urban Wall	Climb	MOVE OUT	Front H & A
End	Patrol	ATTENTION	Tactile
Iteration 3			
Obstacle	**Activity Type**	**Signal**	**Communication Condition**
Start Point	Patrol	MOVE OUT	Front H & A
Pipe Crawl	Crawl	HALT	Front H & A
Hill	Patrol	MOVE OUT	Rear H & A
Low Crawl	Crawl	RALLY	Tactile
Kneeling	Fire	HALT	Front H & A
Prone Supported	Fire	ATTENTION	Tactile
Urban Wall	Climb	RALLY	Tactile
Stairs	Climb	MOVE OUT	Rear H & A

2.5 Experimental Design

2.5.1 Independent Variable

The independent variables were the signal modality (tactile signals, hand and arm signals from the front, and hand and arm signals from the rear) and the obstacle type (patrol, fire, crawl, or climb).

2.5.2 Dependent Variables

The dependent variables for the IMT trials were

- Data collectors' observations of the Soldiers completing the IMT course.
- Whether the Soldier responded to the command.
- Whether the Soldier made the correct response to each command.
- Time from the initiation of command to the Soldiers' response to the command.
- Soldiers' overall ratings of the IMT course negotiation with the tactile system.

2.6 Limitations

The IMT course made it much easier to see the hand and arm signals than if the experiment had been conducted in wooded terrain where vegetation and terrain features could have masked the leaders more. However, the IMT course made conditions identical for each run. Also the experiment was conducted only during daylight conditions, which made it easier to see hand and arm signals than if the experiment had been conducted at night. The fact that the Soldiers wore IBA without ceramic insert plates could have influenced the ease of tactile communication; the plates may have interfered with tactile signal detection and interpretation.

3. Results

3.1 Demographics

Thirty enlisted personnel in the ranks of E-1 through E-4 served as the experimentation Soldiers. All the Soldiers had an infantry MOS of 11. Their average time in service was 10 months. Soldiers' heights ranged from the 8th to the 96th percentile and their weights ranged from the 1st to the 99th percentile. Detailed demographic results are provided in appendix C.

3.2 Training

Very little time was required to train the Soldiers to become accurate in interpreting the tactile signals and for refresher training on the hand and arm signals. Soldiers became proficient after approximately 7 to 10 minutes of individual training on the tactile signals and rated them as easier to learn than the hand and arm signals. All the Soldiers rated the training as being "good" to "extremely good". Detailed training questionnaire results are included in appendix C.

3.3 Woodland IMT Course Trials

Because of a floor effect in the time to respond to signals (the lowest possible time is 0.1 second), the data are highly skewed. This is illustrated in the average response times for all conditions combined as shown in figure 1.

Analysis of variance (ANOVA) is based on the assumption that the data are approximately normally distributed, i.e., the distribution would look like a bell curve. When the data set is markedly skewed, it is common practice to do a logarithmic (log10) transformation to achieve a better approximation of normality. Figure 2 shows the distribution of the mean response times after the logarithmic transformation. It is clear that the logarithmic transformation was successful in producing a better approximation of a normal distribution.

All ANOVAs and ensuing comparisons reported here were done with the logarithmic transformed data. However, when the statistics were run on the logarithmic transformed data and the un-transformed data, the results were virtually identical in all cases.

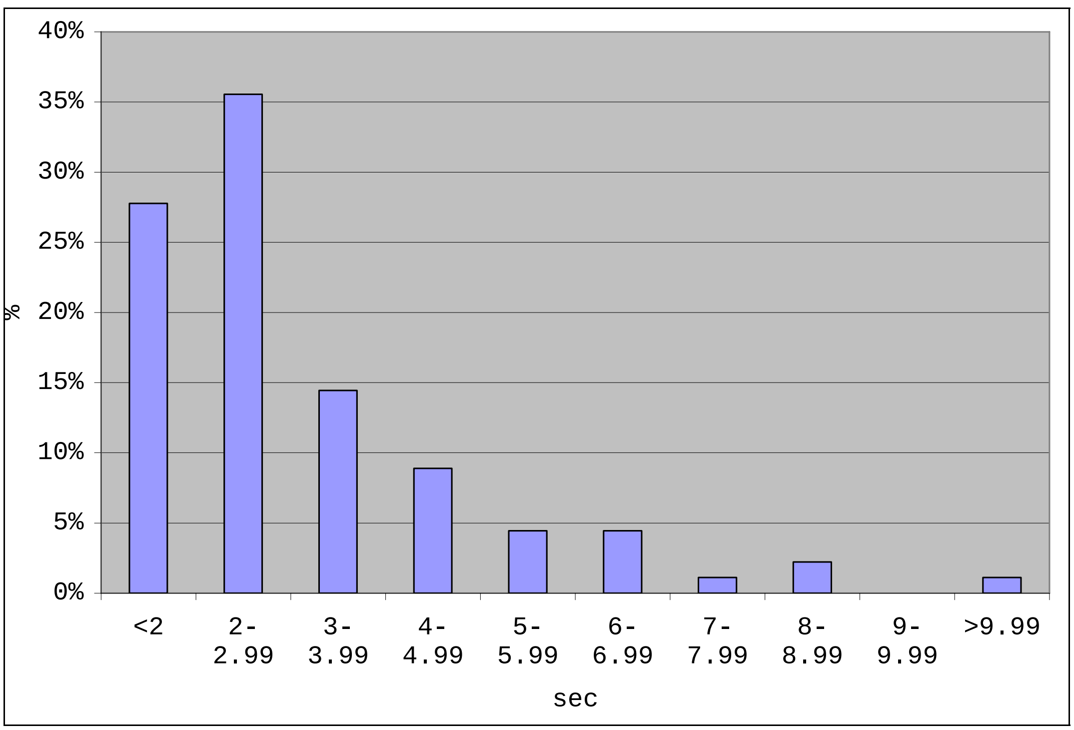

Figure 1. Distribution of mean response times (seconds).

Tables 2 and 3 show the mean response times across the three IMT iterations for the three methods of signaling. For purposes of analysis, failures to respond to signals were coded as response times of 20 seconds.

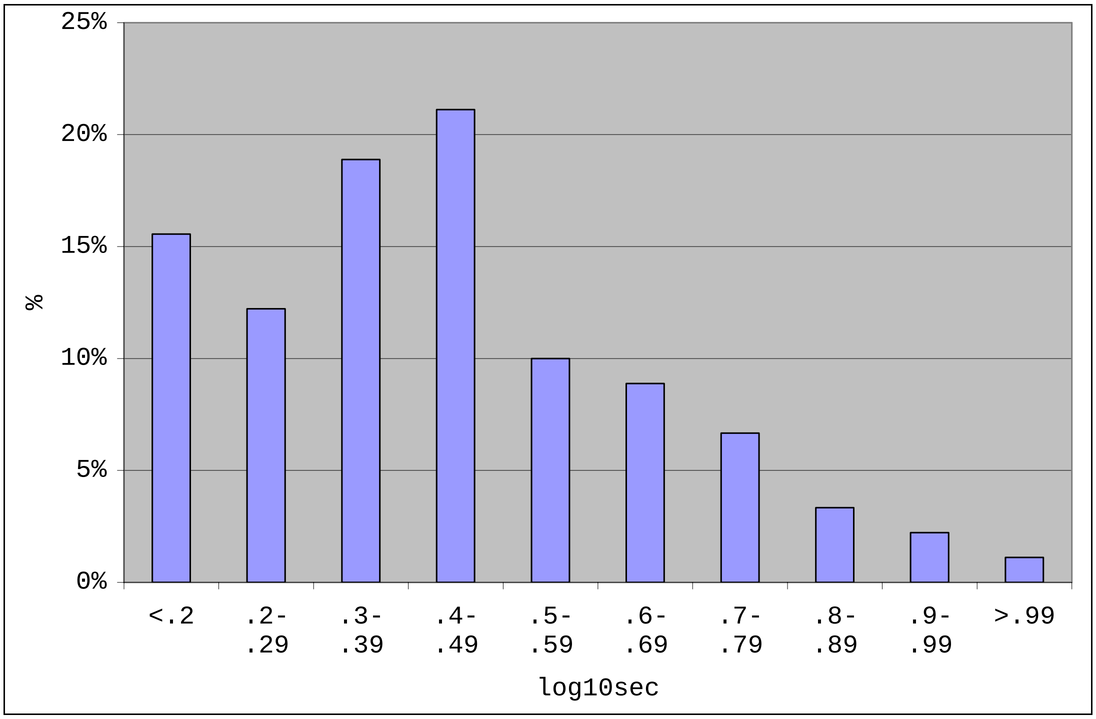

Figure 2. Distribution of logarithmic mean response times (seconds).

Table 2. Mean response times.

Signal Modality	Mean	SD
Hand signals -- rear	4.65	2.02
Hand signals -- front	2.93	1.17
Tactile signals	1.81	0.64

SD = standard deviation

Table 3. Mean logarithmic response times

Signal Modality	Mean	SD
Hand signals -- rear	0.63	0.17
Hand signals -- front	0.44	0.14
Tactile signals	0.24	0.12

A repeated measures ANOVA was performed on the logarithmic transformed scores (see table 3). This analysis yielded a statistically significant effect for signal modality: $F(2,58) = 80.3$, $p < 0.001$, $\eta_p^2 = 0.735$. Ensuing pairwise comparisons were done with Holm's Sequential Bonferroni correction to control for family-wise error (see table 4). These ensuing comparisons show that response times were significantly faster with the tactile signals than with the hand signals and that response times were significantly faster when the hand signals came from the Soldier's front rather than the rear.

Table 4. Ensuing comparisons, mean logarithmic response times.

Comparison	df	t	Obtained p	Required p
Rear versus Front	29	5.92	< .001*	0.05
Rear versus Tactile	29	12.03	< .001*	0.0167
Front versus Tactile	29	7.25	< .001*	0.025

$p < .05$, two-tailed

In order to examine the possibility that extraneous variables might have influenced response latency, logarithmic response times were correlated with the following variables:

- Iteration: 1, 2, or 3
- Order of signal within iterations: 1 through 8
- Type of Obstacle: Fire, Patrol, Crawl, or Climb
- Command: Halt, Attention, Move out, Rally
- Signal modality: Hand – rear, Hand – front, Tactile

Table 5 shows the bivariate correlations between each of these variables and logarithmic response times.

Table 5. Correlations with mean logarithmic response times, n = 719 observations.

	Bivariate Correlations		Obstacle Partialed Out	
Variable	**r**	**p**	**r**	**p**
Iteration	0.01	0.87	-	-
Order	0.13	< .001	0.05	0.138
Obstacle	0.22	< .001	-	-
Command	0.17	< .001	0.02	0.522
Modality	0.46	< .001	0.47	< .001

In addition to “signal modality,” the extraneous variables of “order,” “obstacle,” and “command” each had small but statistically significant correlations with logarithmic response time. Of these extraneous variables, “obstacle type” had the highest correlation with response latencies. The effect of obstacle type is shown in table 6. A repeated measures ANOVA indicates that there was a statistically significant difference in logarithmic response latencies among the four types of obstacles: $F(3,87) = 12.8$, $p < 0.001$, $\eta_p^2 = 0.307$.

Table 6. Mean response times as a function of obstacle type.

Obstacle Type	Mean	SD
Firing	2.38	0.84
Patrolling	2.76	1.10
Crawling	3.25	2.40
Climbing	4.13	1.84

Ensuing pairwise comparisons (table 7) indicate that responses were slowest when the Soldiers were engaged in climbing events and that when the Soldier was in a stable firing position, he responded faster than when he was crawling or climbing.

Table 7. Ensuing comparisons, mean logarithmic response times as a function of obstacle type.

Comparison	df	t	Obtained p	Required p
Crawl versus Fire	29	2.70	0.012*	0.0167
Crawl versus Climb	29	2.80	0.009*	0.0125
Crawl versus Patrol	29	0.95	0.348	0.05
Fire versus Climb	29	6.49	< .001*	0.0083
Fire versus Patrol	29	1.73	0.094	0.025
Climb versus Patrol	29	4.60	< .001*	0.01

**p < .05, two-tailed*

The statistical technique of partial correlation can be used to interpret the positive correlations between logarithmic response times and the "order" and "command" variables. In a partial correlation, two variables are correlated ("order" and "time" or "command" and "time") while we control for the effects of a third variable ("obstacle type"). An analysis of partial correlations indicates that the small but statistically significant relationships between logarithmic response times and the "order" and "command" variables are artifacts of the "obstacle type" variable. As shown in table 5, when "obstacle type" is statistically controlled or partialed out, the correlations between logarithmic response times and the "order" and "command" variables become non-significant. Order correlated with logarithmic times only because the climbing obstacles, which had longer latencies, come at the end of the IMT course. Partialing "obstacle" has no substantial impact on the correlation between logarithmic response times and "signal modality".

The next analysis examines the effect of "signal modality" within each of the four obstacle types. Table 8 shows the mean response latencies for the three "signal modalities" as a function of obstacle type. These means are illustrated in figure 3. This graph shows that the type of obstacle influenced response latencies for hand signals but not for tactile signals. As shown in table 9, "signal modality" had a statistically significant effect within each obstacle type.

Table 8. Mean and standard deviation response times as a function of signal modality and obstacle type.

Modality	Fire	Walk	Crawl	Climb
Tactile	1.84(1.64)	1.84(0.80)	1.76(0.61)	1.80(0.77)
Front	1.63(0.71)	2.27(0.74)	3.93(3.94)	3.89(1.75)
Rear	3.66(1.89)	4.17(2.97)	4.07(3.25)	6.71(4.91)

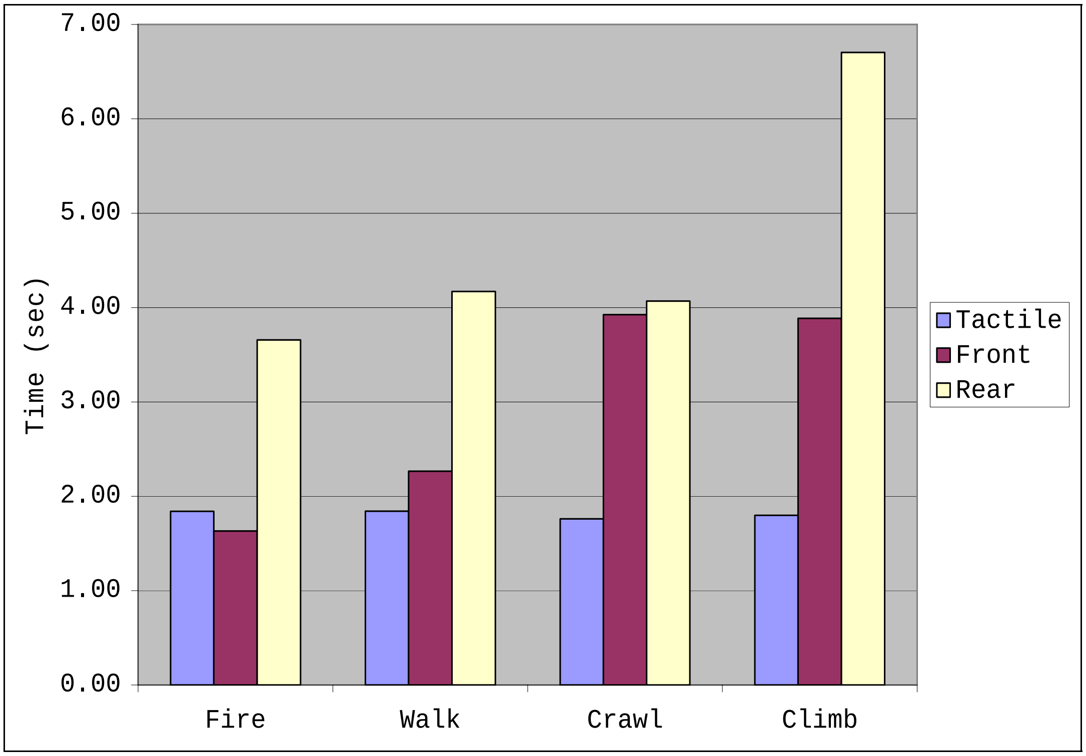

Figure 3. Mean response times as a function of signal modality and obstable type.

Table 9. Summary of repeated measures ANOVAs, logarithmic response times as a function of signal modality within each obstacle type.

Obstacle	F	df	p	η_p^2
Fire	31.8	2,58	< .001	0.523
Patrol	22.4	2,58	< .001	0.436
Crawl	30.6	2,58	< .001	0.513
Climb	55.7	2,58	< .001	0.658

Table 10 shows the results of ensuing pairwise comparisons of the three signal modalities within each obstacle type. Soldiers responded significantly faster to tactile signals than to hand signals from the rear in all obstacle conditions. Responses to tactile signals were significantly faster than responses to front hand signals for all obstacle types except “firing positions”. Front hand signals produced faster response than rear hand signals in all obstacles except “crawling” events.

Table 11 shows the proportion of correct and incorrect Soldier responses to the signals as a function of signal modality. There was a significant difference in correct responses among the three modalities: χ^2 (df=2) = 24.0, p < 0.001. Further analysis shows that the correct response rate was lower in the “hand-rear” condition relative to the other two signal conditions: χ^2 (df=1) = 20.6, p < 0.001. There was no significant difference in the proportion of correct responses between the “hand-front” and “tactile” conditions.

Table 10. Ensuing comparisons, signal modalities within obstacle type.

Obstacle	Comparison	df	t	Obtained p	Required p
Fire	Tactile versus Front	29	0.55	0.585	0.05
	Tactile versus Rear	29	6.19	<.001*	0.025
	Front versus Rear	29	7.40	<.001*	0.0167
Patrol	Tactile versus Front	29	2.72	0.011*	0.05
	Tactile versus Rear	29	6.39	<.001*	0.0167
	Front versus Rear	29	3.83	0.001*	0.025
Crawl	Tactile versus Front	29	5.51	0.001*	0.025
	Tactile versus Rear	29	7.29	0.001*	0.0167
	Front versus Rear	29	1.09	0.383	0.05
Climb	Tactile versus Front	29	9.11	0.001*	0.025
	Tactile versus Rear	29	9.18	0.001*	0.0167
	Front versus Rear	29	3.33	.002*	0.05

Table 11. Proportion of correct responses.

	Tactile (percent)	Front (percent)	Rear (percent)
Correct	95.3	98.3	87.8
Incorrect	4.7	1.7	12.2

An additional analysis of the missed responses was conducted to separate them into “failures to detect” the commands versus “incorrect responses” to detected commands. Figure 4 shows the number of failures to detect commands, of a total of 720 commands, by “signal modality” and “obstacle”. There was a significant difference in the number of “failures to detect” among the three signal modalities: χ^2 (df=2) = 18.5, $p < 0.01$. There was also a significant difference in the number of “failures to detect” among the four obstacle types: χ^2 (df=3) = 7.82, $p < 0.05$. The greatest number of “failures to detect” came with the “hand signals from the rear” and on the “climbing obstacles”.

The number of incorrect responses to detected commands is illustrated in figure 5. There was no significant difference in incorrect responses for either the “signal modalities” (χ^2 (df=2) = 5.39) or the “obstacle types” (χ^2 (df=3) = 5.54). There was a non-significant trend for the greatest number of incorrect responses occurring with the “hand signals from the rear” and “on the climbing obstacles”.

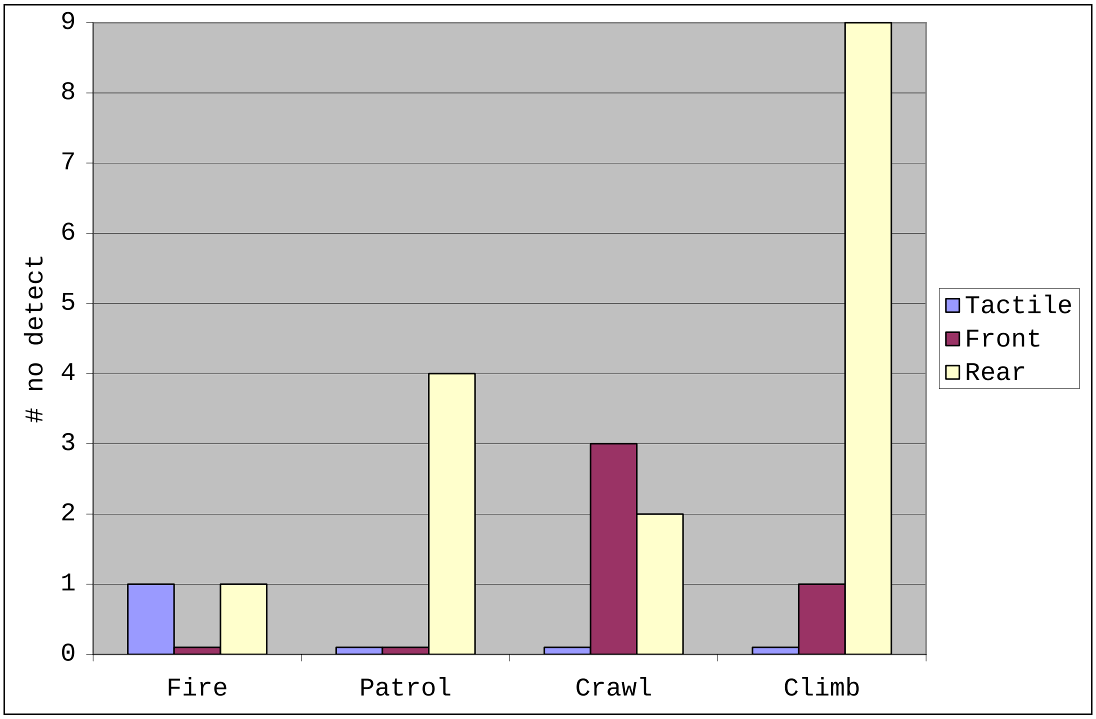

Figure 4. Failures to detect command as a function of signal modality and obstacle type.

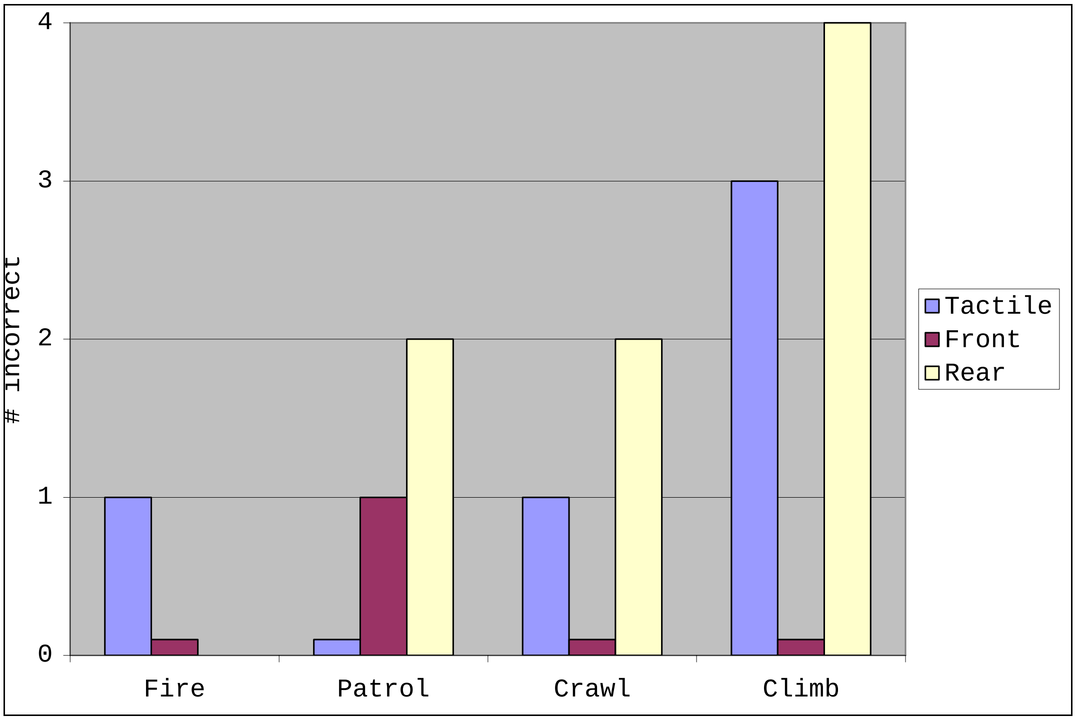

Figure 5. Incorrect responses as a function of signal modality and obstacle type.

3.4 Soldier Questionnaire Responses

Soldiers rated the "hand signals" and the "tactile signals" as being very easy to learn. Soldiers rated the "tactile commands" and the "front hand commands" as very easy to detect and interpret. One Soldier stated that the tactile system seemed to become progressively easier to interpret as the iterations progressed. By the third iteration, he stated that the tactile belt was easier and quicker to understand than clearly visible hand and arm signals. The "rear hand signals" were rated as being more difficult to detect and interpret.

Figure 6 shows the mean ratings for detecting specific signals at specific obstacle types (1 = "extremely difficult"; 7 = "extremely easy"). For each obstacle type, Soldiers rated the "rear hand signals" as being more difficult to detect and interpret than the "tactile signals" or the "front hand signals".

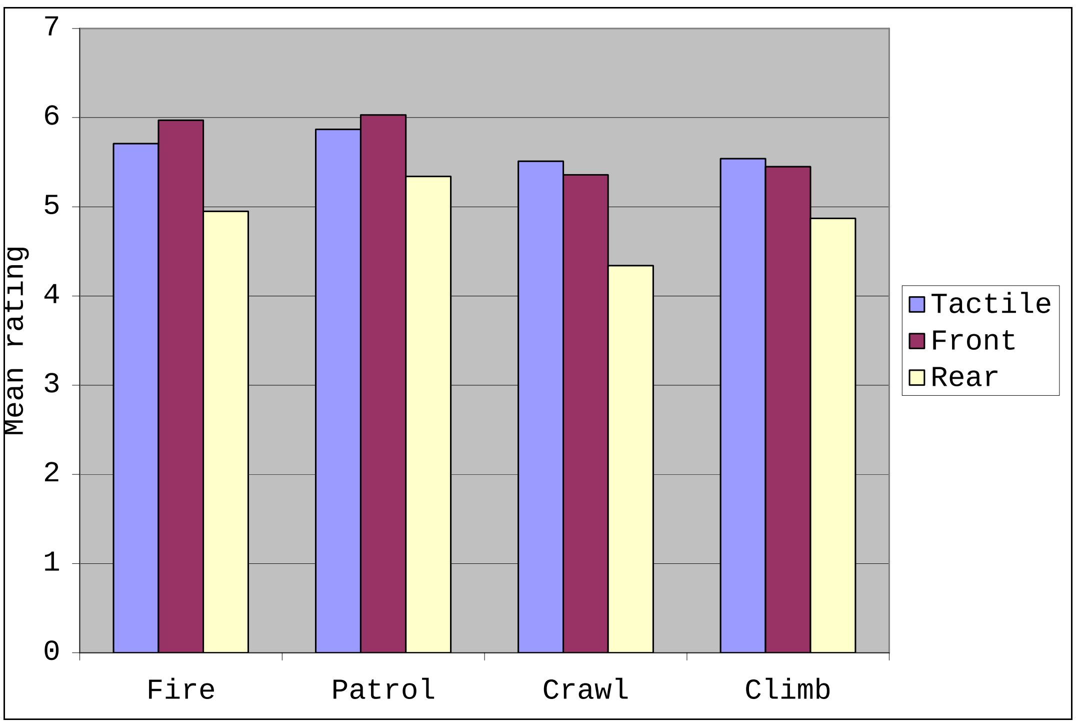

Figure 6. Mean ratings of ease of signal detection.

Soldiers indicated that the tactile system allowed them to focus more attention on negotiating obstacles and that it would be useful in tactical situations in which they would need to focus on other tasks such as security. Soldiers commented that it was very difficult to receive a visual hand and arm signal at certain points on the course where their full attention was given to negotiating the obstacle or when they could not maintain visual contact with the leaders.

Soldiers stated they knew immediately when they received a tactile signal no matter what obstacle they were negotiating. Soldiers also commented that it became more difficult to interpret tactile signals when the signal strength weakened because of low battery power.

Suggestions for improvement included reducing the size of the battery, placing the unit in the cargo pocket, and decreasing battery consumption. See appendix C for detailed questionnaire results.

4. Conclusions

The tactile signal patterns were found to be intuitive and easy for the Soldiers to understand. Very little training time (less than 10 minutes) was required for Soldiers to become accurate in interpreting the four tactile signals used during the experiment. Results demonstrated that Soldiers performing IMT were able to receive, interpret, and accurately respond to the tactile commands faster than when the information was passed by a leader in the front of a wedge formation or by a leader in the back of a wedge formation using conventional hand and arm signals. Soldiers also commented they were better able to focus more attention on negotiating obstacles and on local area SA when they were receiving tactile signals than when maintaining visual contact with their leaders in order to receive standard hand and arm signals.

The use of a tactile communication system can improve infantry team performance beyond that documented in this experiment. During this experiment, leaders in the front and rear of the Soldiers were not obscured by terrain, vegetation, or light level. In other words, the conditions of this experiment were optimal for the Soldiers' abilities to see the conventional hand and arm signals. During combat situations, larger dispersions and obscurants could greatly inhibit reception of visual hand and arm signals. Visual barriers in an urban combat situation could impair hand and arm signaling. Also, hand and arm signals are traditionally passed along throughout the squad so that the time when the first squad member receives the signal could be much quicker than the time when the signal is passed to and received by the last squad member. A tactile communication system would allow simultaneous reception of signals by all squad members. For example, a "halt" signal sent by visual signals could result in a wave effect so that the last squad member to receive the signal could still be moving long past the time when the squad needed to stop. A "halt" signal sent by a tactile system could be received by all squad members in less than 2 seconds. A further benefit provided by a tactile system is the increased local SA experienced by the squad because the tactile system would free their eyes from having to watch for visual signals. A third benefit of adding a tactile system is the fact that Soldiers would have two means of receiving communication because the visual hand and arm signals would still be available for use.

Suggestions for improvement of the tactile system include reduction of battery consumption and reduction of battery and receiver unit sizes.

5. Recommendations

This experiment demonstrated that the addition of a tactile communication system creates the potential for increasing dismounted Soldier performance. Additional work should be accomplished to expand the lexicon of tactile language. A study should be conducted to document the upper boundary on the number of tactile commands that can easily be interpreted and understood by Soldiers operating in tactical environments such as military operations in urban terrain and wooded terrain. Work should be performed to evaluate the potential of incorporating the PDA transmitter function into PDAs or other computer systems already being planned for the dismounted Soldier. Evaluation of the potential for using a power source that is already planned for the dismounted Soldier should be performed. Finally, development of a means to send the tactile signals that do not require the removal of the Soldier's hands from his weapon should be initiated.

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Appendix A. UCF Contractor's Report (with minimal correction)

Deliverable: CONTRACTOR REPORT (DRAFT)

To: Dr. Elizabeth S. Redden, Chief, USAIC-HRED, Field Element, Army Research Laboratory, Ft. Benning, GA

From: Dr. Richard Gilson (PI), LTC James Merlo, and Shawn Stafford
University of Central Florida

Service: Contractor support for ARL evaluation experiment

Subject: Evaluation of Soldier tactile and arm and hand signals on an obstacle course

Date: February 25, 2006

The University of Central Florida (UCF) developed and produced a state-of-the-art tactile prototype display for Soldiers with signals presented around the torso in the abdomen area. The development and laboratory research for this design included a review of past literature and basic experiments conducted at the University of Central Florida to determine the preferred placement, frequency, duration, sequencing, etc. for intuitive tactile messages. To date only limited field research has been conducted using (sic) the prototype display units. Accordingly, UCF provided equipment and support to the Army Research Laboratory located at Fort Benning, Georgia, to conduct an assessment of these prototypes conveying standard Army hand signals to Soldiers via touch while engaged in an obstacle course. For operational validation, the Soldiers wore full field gear, including elbow and knee pads, over tactical vests and carried simulated M4 rifles. The following report is a brief synopsis of support activities and observations by University of Central Florida researchers. The results of the empirical data collection and a full report of the findings are being prepared by the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) at Fort Benning, GA, under the direction of Dr. Beth Redden.

Equipment

Each tactile display assembly included eight custom-built electro-mechanical vibrotactile devices, hereafter known as "tactors" (see figure A-1). These eight tactors and their associated wiring were securely fitted into an elastic belt worn snugly around the torso (above the navel but below the sternum). This arrangement created a ring of equidistant stimulation loci with the first one centered just above the navel. A photograph of an exemplar tactor is shown in figure A-1. The center piston, visible with a midpoint screw, moves within larger fixed housing.

Figure A-1. Photograph of a single tactor, model C2, manufactured by Engineering Acoustics, Inc. These tactors are essentially acoustic transducers that transmit 200-300 Hz sinusoidal vibrations onto the skin. The mass of each tacton is 17 grams.

The tactor controller box (TCB), designed by Engineering Acoustics, Incorporated, is powered by a 9.6-volt rechargeable battery (or six AA replaceable batteries). The TCB fires sequences of tactors in pre-coded patterns [specified by UCF] and actuates the individual tactors according to predetermined stimulus parameters [specified by UCF]. The sequences used for the ARL experiment were programmed and stored in the hardened TCB. The TCB wiring connects to the tactor belt through a cable (see figure A-2). The Soldiers wore the entire TCB and its battery pack in their right cargo pocket of either their BDUs or ECUs; participants wore both types. The sequences were activated remotely by means of a wireless Bluetooth personal data assistant (PDA). The software used to send signals to the TCB was designed by RIMLine llc in conjunction with and under the direction of University of Central Florida researchers. Photographs of the actual equipment are shown in figure A-2.

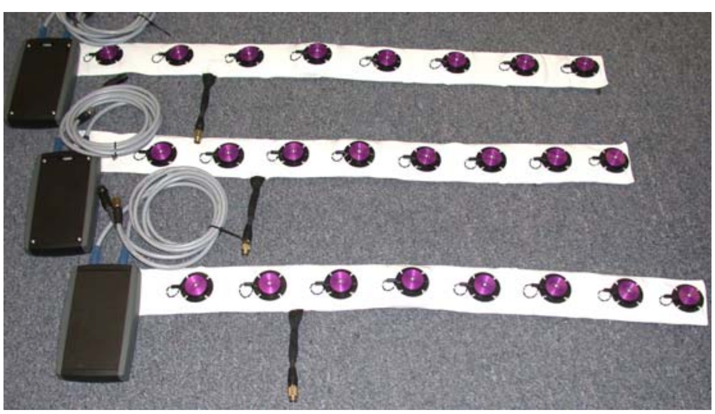


Figure A-2. Three tactile displays belt assemblies are shown above along with their tactor controller boxes (TCBs). Each box includes a wireless Bluetooth receiver and the controlling circuitry. The picture on the right is the advanced robotics controller (lightweight) PDA that remotely sends the selected signal to the TCB to trigger the tactile message.

Tactile Signals

The four hand signals chosen for the experiment were "Attention," "Halt," "Rally," and "Move Out". The tactile representations of these signals were designed in a collaborative effort of scientists at the University of Central Florida and a consultant group of subject matter experts (SMEs) consisting of former U.S. Soldiers (1 Navy Seal, 1 Marine Force Recon, 1 Army Ranger, and 1 Army Special Forces Soldier). These sequences were then slightly modified in laboratory testing at the University of Central Florida and developed for this field test.

A brief description of the signals follows:

- Attention – sequenced side-to-side activation of front tactors, creating a "wave-like" motion
- Halt – four tactors simultaneously actuated
- Move Out –sequenced back-to-front activation of tactors, creating movement around each side of the body to converge in the front
- Rally –sequenced activation of all tactors, creating a circular motion around the body

The signals were separated individually from their originally intended operational sequences to test their individual reliability independently. Note the use of sequenced signals initially came from feedback from our SME team who suggested that an attention signal generally should be used to alert a Soldier of an incoming command, such as move-out or rally. However, the goal of this field test was to test each signal independently of the other signals, so no preparatory signal was used.

Prior studies suggested that these field tests should work well. Physiological data collected in a laboratory at West Point showed that Cadets, even while under 80% max (sic) heart rate (induced by subjects running on a treadmill), were easily able to detect these signals. The purpose of this experiment was to determine whether Soldiers can both detect and understand these signals while completing a physically and attention demanding obstacle course, all within a more applied setting.

Tactile Training

The following experimental protocol was designed exclusively by personnel from HRED of ARL. Each Soldier was given 7 to 10 minutes of familiarization with the tactile system before completing the obstacle course. Familiarization for every Soldier consisted of approximately 17 repetitions of the four tactile signals: three repetitions without equipment, 4 times with equipment, and 2 times each in the kneeling, prone, combat roll, walk, and run positions/actions. Just before the Soldier started the obstacle course, a researcher presented and reviewed each tactile signal again to make sure the Soldier understood the signals.

Obstacle Course Testing

Each of 30 male Soldiers went through an IMT-Like obstacle course four times for a total of 120 trials. The first trial was for training only, and the next three included data collection. During each trial, the Soldier moved out “on patrol” while spaced between two NCOs[2], one of whom was approximately 10 paces in front (simulating a team leader) and the other was about 10 paces behind (simulating a squad leader). The Soldier’s mission was to negotiate each obstacle, while looking for hand signals from the front NCO, the rear NCO, or from the tactor belt with its wireless signals sent by a researcher. Nine signals (3 per condition, front, rear, or tactor) were given at different predetermined locations, and changed (sic) for each trial. At the same time, the Soldier was to maintain his scan and to call out if he spotted one of three shoulder badges/tabs that were placed on the ground [Airborne, Ranger, Special Forces]. Typically, a Soldier was able to spot one of the three badges during the seven minutes on average it took to complete the entire obstacle course. The main dependent variable was the time from the initiation of each signal to the time the Soldier called out that signal [accuracy was also recorded].

Informal Observations of the Tactile Signals

The UCF research team observed what appeared to be an intuitive grasp of the tactile signals by all the Soldiers, typically evidenced by rapid mastering of tactile commands after only three to four presentations during the training. Soldier response times for tactile signals during testing appeared quite consistent and somewhat faster than visual signals from the front and clearly superior to those presented visually from the rear position. It also appeared that during training as well as during the obstacle course trial itself that Soldier accuracy in identifying tactile commands was exceptional, despite the short period for training. Interestingly, these Soldiers who were taught arm and hand signals in basic training and again in AIT[3], made a number of errors on the arm and hand signals. This usually occurred while they were looking from the prone position or while engaged in a physical act. Comparatively, the newly learned tactile signals appeared unaffected by body orientation or ongoing physical movement.

Observations of the Hardware

The prototype systems proved durable enough to allow 30 Soldiers to complete 120 trials through the 400-yard course with challenging obstacles. Notably, these same prototypes endured UCF, West Point, and the Naval Post graduate school testing and demonstrations in the prior 6 months to this evaluation, including laboratory experiments, treadmill studies involving physiological stress, and numerous presentations while on travel.

[2] non-commissioned officers
[3] advanced individual training

NCO feedback

The NCOs provided valuable feedback. In particular, they suggested that often-occurring "breaks in contact" should be far less likely with tactile communication. "Breaks in contact" take place in movement formations when Soldiers fail to receive or pass on visual arm and hand signals within a formation. NCOs also stated that night conditions and/or thick vegetation increase the response times for visual signals and that time delays in visually acquiring even an obvious hand signal can balloon by 4 times in a four-Soldier team as the signal is relayed across the team. In contrast, a demonstration of tactile signals with a four-Soldier fire team showed simultaneous receipt by each team member for the tested commands [i.e., "Move Out" and "Halt"].

Soldier Feedback

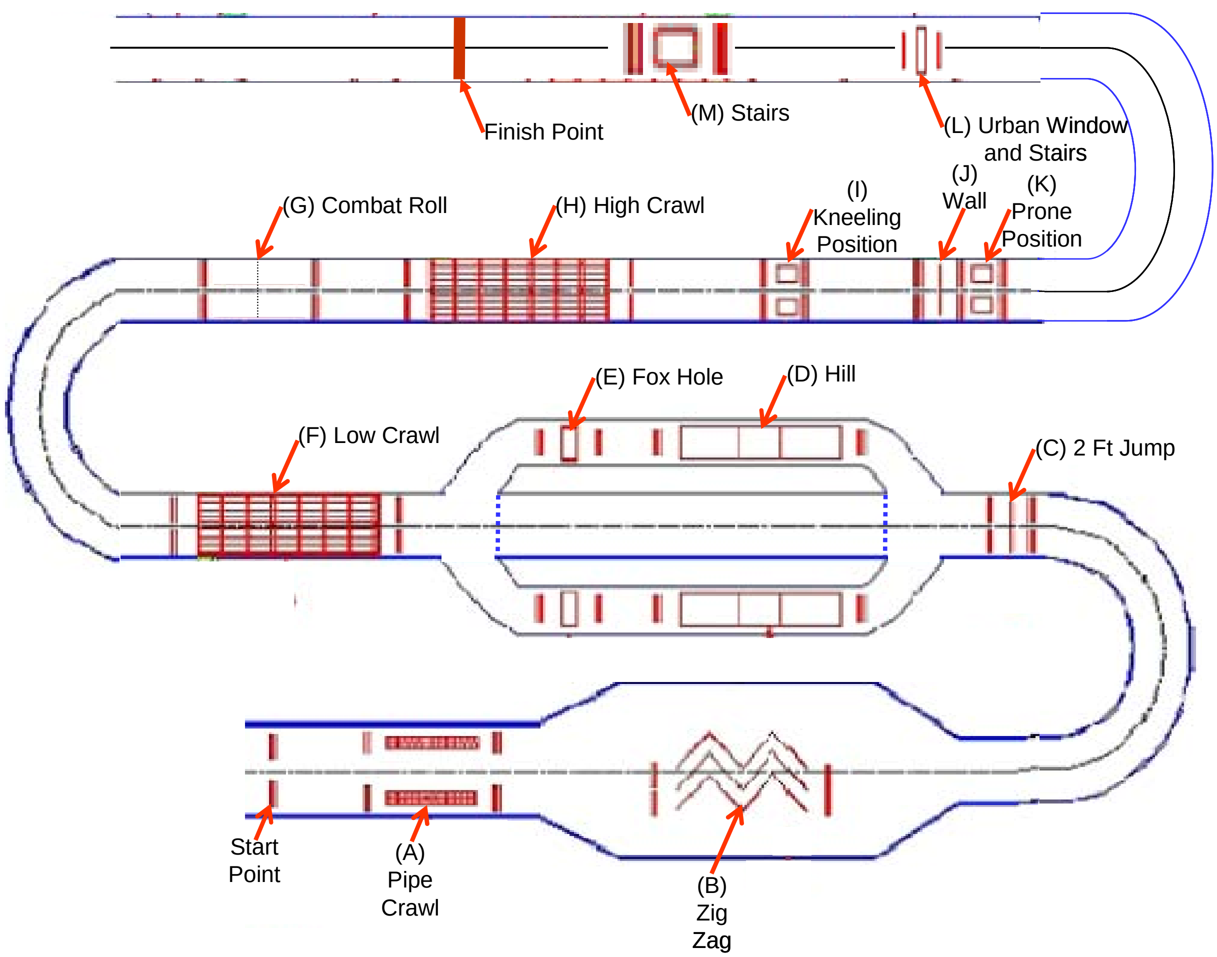
- Tactile arm and hand signals were easy to discriminate and identify quickly, without accuracy issues
- Tactile system was comfortable to wear
- System did not interfere with normal operations during IMT or on the obstacle course
- Soldiers throughout the trials continued to offer possible applications for the tactile display and ideas for a tactile language
- Soldiers wanted more tactile-coded arm and hand signals for expanded capability.
- Soldiers expressed less difficulty with the normally divided tasks of looking around for obstacles (such as landmines) or looking in the distance for enemy activity, if hand signals were presented by touch rather than as another competing visual task.

UCF-Considered Refinements

- Different connections between the tactor controller box and tactile belt to increase overall field worthiness, perhaps wireless.
- Timing modifications for tactile patterns to facilitate absolute identification within sequences of messages, e.g., "Halt-Move Out/Direction-Rally" to help ensure error-free identification.
- Comparing the need for preparatory commands in the field, when surrounded by contextually rich environments, versus in the laboratory where preparatory commands may not be as essential.
- Detailed assessment of theoretical reductions in cognitive requirements and workload using touch as a parallel channel for information.

On behalf of the UCF research team, we would like to express our sincere gratitude to the U.S. Army Research Lab at Fort Benning, GA, for allowing us to support and observe this experiment. A special thanks goes (sic) to those Soldiers who performed as participants, many of whom are preparing to enter the operational Army to defend our nation. A blessing to them and to their families for all that they do.

Appendix B. IMT Course Layout



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Appendix C. Soldier Questionnaire Results

DEMOGRAPHICS

SAMPLE SIZE = 29

SEX	**MOS**	**RANK**
Male – 29; Female - 0	11B – 28; 11C - 1	E-1 – 8 E-3 – 10 E-2 – 7 E-4 - 4

AGE	**TIME IN CURRENT DUTY POSITION**
21 (mean)	10 months (mean)

1. What is your height? _70 inches_ (range is 65-74)

2. What is your weight? _176 pounds_ (range is 120-242)

3. Do you smoke? _6_ Yes _23_ No

4. Are you color blind? _0_ Yes _29_ No

5. Which is your dominant eye? _5_ Left _24_ Right

6. Do you wear prescription lenses? _12_ Yes _19_ No

7. If yes, which do you most often wear? _6_ Glasses _6_ Contacts

8. Are you left-handed, right-handed, or ambidextrous?

   _2_ Left-handed _26_ Right-handed _1_ Ambidextrous

9. Have you ever served in combat or in a hostile fire zone?

   _0_ Yes _29_ No

TRAINING

SAMPLE SIZE = 29*

1. Using the scale below, please answer the following questions which are based on your training for the Tactile system.

1	2	3	4	5	6	7
Extremely bad	Very bad	Bad	Neutral	Good	Very good	Extremely good

	MEAN RESPONSE
Length of training	5.79
Level of detail	6.29
Mix of lecture to hands-on exercise	6.31
Overall quality of training	6.34

2. Using the scale below, evaluate your ability to detect and understand each of the tactile signals based on your training today.

1	2	3	4	5	6	7
Extremely bad	Very bad	Bad	Neutral	Good	Very good	Extremely good

TACTILE SIGNAL	MEAN RESPONSE
Halt	6.44
Move out	5.96
Rally	6.22
Attention	6.22

3. Using the scale below, evaluate your ability to detect and understand each of the Hand and Arm signals.

1	2	3	4	5	6	7
Extremely bad	Very bad	Bad	Neutral	Good	Very good	Extremely good

HAND AND ARM SIGNALS	MEAN RESPONSE
Halt	6.64
Move out	6.61
Rally	6.43
Attention	6.18

* All 30 Soldiers completed training, but one Soldier failed to complete the training survey.

WOODLAND IMT

SAMPLE SIZE = 30

1. Using the scale below, please rate how easy or hard it was to see (or feel) each of the 8 signals you received during this trial. Each signal is identified by the location on the obstacle course and by the type of signal given.

1	2	3	4	5	6	7
Extremely hard	Very hard	Hard	Neutral	Easy	Very easy	Extremely easy

Iteration 1		
Signal No.	**Location: Command**	**Mean**
1	Pipe crawl: Tactile	5.17
2	First bend: Rear	5.47
3	Prone firing position: Front	5.70
4	Second bend: Tactile	5.73
5	High crawl: Rear	4.43
6	High wall: Tactile	4.97
7	Urban wall window: Rear	4.77
8	Stairs: Front	5.70

Iteration 2		
Signal No.		
1	Zigzag: Front	5.76
2	Kneeling firing position: Rear	5.14
3	Low crawl: Front	4.90
4	Combat roll: Tactile	5.17
5	High crawl: Rear	4.24
6	High wall: Rear	4.50
7	Urban wall: Front	5.21
8	End point: Tactile	6.00

Iteration 3		
Signal No.	**Location: Command**	**Mean**
1	Start point run: Front	6.31
2	Pipe crawl: Front	5.83
3	Hill: Rear	5.21
4	Low crawl: Tactile	5.86
5	Kneeling firing position: Front	6.24
6	Prone firing position: Tactile	6.24
7	Urban wall: Tactile	6.10
8	Stairs: Rear	5.24

2. Using the scale below, how easy or hard was it to do the following?

a. See (or feel) the signal:

	Mean
From the Front	6.14
From the Rear	4.63
With Tactile belt	6.19

b. To interpret the signal:

	Mean
From the Front	6.02
From the Rear	4.97
With Tactile belt	6.03

c. To learn the signals:

	Mean
Army Hand & Arm signals	6.13
Tactile signals	6.43

Comments	**No. of Responses**
This system is great!	3
I think that this system is a good idea and worth the investment.	2
I liked them. Easy to use and not always having to look around. You can focus on your mission.	1
The system seemed to become progressively more and more communicable as the iterations progressed up to the third iteration. By the third iteration, the tactile belt was easier and quicker to understand than clearly visible hand and arm signals.	1
Adaptation to the tactile system is fairly quick. Tactile system response time to signals is faster than hand signals alone.	1
The reaction time with the communication systems were generally consistent as opposed to the hand signals. This can definitely help out with moving large amounts of people and coordinating movements.	2
Found it very easy to know what signal or action I needed to perform with the belt. As to where, I found my self guessing on some of the rear hand signals.	1
Overall, the tactile belt had major advantages over conventional hand signals. The only major concerns with the use of the tactile belt would be when interacting with equipment that produces loud noises or a lot of vibrations.	1
Still like the belt. I think as long as you are trained on the system it will work well.	1
Signal strength was extremely low resulting in missed and confused interpretations.	1
The batteries on the belt were not as strong, so it was hard to distinguish while crawling.	1
It was a bit difficult to distinguish the tactics signals due to a low battery.	

Still had some trouble making out the signals; I had to second guess myself once in a while.	2
Battery system bulky. Unreliable with current power source.	1
Needs a better power source; other than that, no problems.	1
Battery strength was lower leading to less vibration felt from the belt.	1
The box in my cargo pocket caused some discomfort during the crawling portion.	1
The belt was better with the batteries at full charge. The vibration was stronger with the batteries at full charge.	1
Potential sound from the sensors vibrating against bone or solid structures.	1
Use more iterations with the tactile belt.	1
It is hard to make out the belt signals when you are doing a combat role, or are in the prone position. I think the pulses need to be stronger, but not to extreme, when my heart rate was up it made it harder	1
I think the vibration in the belt should be intensified a little bit.	3
Clashed with body location and current gear.	1
Additional training and time is needed with the belt to allow it to become almost second nature for reacting to vs thinking of the belt directly.	1
The different signals on the tactile belt were very easy to distinguish from each other regardless of position or activity. I had more of a delayed reaction with the hand signals.	1
Battery/computer are slightly bulky in the cargo pocket.	1
I'm not so sure how it will work under combat conditions. I have never been in combat but I do know that when your adrenalin is rushing your senses are impaired. The belt requires your senses (sense of touch).	1
During a combat role some motions of the tactile belt become hard to distinguish due to where the gear hits the body.	1
Signals are difficult to see and/or interpret in general, especially with the helmet and gear on. Whereas the tactile system allows you to dedicate more effort to maintaining security and staying in view of your change of command.	1
I believe that the tactics signal for move out should be on one side of the waist as opposed to both sides of the waist to make it easier to distinguish.	1
It is much easier to know there is a communication being sent with the tactile signals. I believe interpretation is simply a matter of using the system more.	1
In this iteration, I noticed that the tactile belt helped with communicating through obstacles. When climbing over the urban wall, I was not able to see the hand signal being given until I cleared the wall. With the belt I would be able to receive the comm..	1
After familiarization with the tactile belt, I found myself waiting for a signal from the belt and focusing visual perception on locating the objectives. Still the signal needs to be stronger and more distinguishable.	1

3. Were there any safety issues or problems with the tactile belt system you used during this trial?

 0 Yes
 30 No

Comments	**No. of Responses**
Well organized course.	2
Reaction time was slowed down due to frequent adjusting of loose kneepads and Kevlar[4].	1
When walking “move out” can feel a lot like “attention.”	1
How well will the device hold up in rough terrain?	1
The use of the tactile belt can actually be safer when negotiating obstacles since the user doesn’t have to look for a hand signal and concentrate on the obstacle.	1
Only one thing, just a smaller battery.	1

[4]Kevlar is a registered trademark of E.I. DuPont de Nemours & Co., Inc.

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